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Biostimulation of Organomineral Amended Asa River Sediment in Ilorin, Kwara State, Nigeria

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ABSTRACT

Globalization and increase in anthropogenic activities has led to heavy metal pollution of most agricultural soils and ecosystem due to large and indiscriminate discharge of toxic effluent into water ways and agricultural lands. An experiment was conducted at the University of Ilorin Dam site to evaluate the effectiveness of three organic wastes singly and in combination with NPK as bio-stimulating agent to remediate Asa River Sediment. Randomized Complete Block design in split plot arrangement was adopted using three local amendments: abattoir effluent (AE), poultry droppings (PD) and rice husk (RH) at two levels. Soil samples collected before and after planting were analysed for heavy metals (Mn, Fe, Pb, Zn, Cu, Co, Ni, Cr, Cd) using Atomic Adsorption Spectrophotometer. The result shows that application of AE was more effective in bioremediating heavy metals in Asa River Sediment with a reduction of 99.07% in soil, 99.82% in maize tissue, and 99.97% in maize grain, as compared to rice husk; 99.04% in soil, 99.81% in maize tissue and 99.96% in maize grain and poultry dropping 98.72% in soil, 99.79% in maize tissue and 99.96% in maize grain respectively. Heavy metals in the remediated soil varied in the order Mn>Fe>Pb>Zn>Cu>Co>Ni>Cr>Cd in soil, plant tissue and grain and were also observed to be below the maximum permissible limit as set by FAO/WHO. The findings of the research shows organic wastes were effective in remediating heavy metal in Asa sediments with abattoir effluent observed to be more effective than poultry droppings and rice husk.

INTRODUCTION

In Nigeria, environmental degradation through the indiscriminate disposal of domestic, agricultural and industrial waste without considering the health and environmental implications is alarming. More often, heavy metals input to agricultural soils may come from inorganic fertilizer applications; other sources of heavy metal input to agricultural soils may include atmospheric decomposition, sewage sludge, agrochemicals, livestock manure, irrigation water, industrial waste and compost (Zhou et al., 2004). Metals are classified as “heavy metals” if in their standard state, they have a specific gravity of more than 5g/cm^3 (Devkota and Schmidt, 2000).

Waste is any substance, solution mixture or article for which no direct use is envisaged but which is transferred for processing, dumping, elimination by incineration or other methods of disposal (Yakowitz 1988).

In developing countries especially Nigeria with high population density and scarce funds available for environmental restoration, low-cost and ecologically sustainable technologies are required to remediate contaminated lands so as to reduce the associated risks, make the land resource available for agricultural production, enhance food security and scale down land tenure problems (Wuana and Okieimen, 2011).

Traditional methods for soil remediation ((i) ex situ (excavation) or in situ (on-site) soil washing/leaching/flushing with chemical agents, (ii) chemical immobilization/stabilization, (iii) electrokinetics (electromigration), (iv) covering the original polluted soil surface with clean soils, (v) dilution method (mixing polluted soils with surface and subsurface clean soils to reduce the concentration of heavy metals, (GOC, 2003; Fawzy, 2008) are often expensive and energy consuming and the elevated costs involved in removal of toxic substances from contaminated soils prevent remediation from being carried out: especially in areas of little economic value. This has given rise to a new ecologically safer method of remediating toxic soil known as Bioremediation which consist of biostimulation, bioaugmentation and phytoremediation (Abioye, *et al.* 2009). Bio-stimulation consists of adding nutrients and other substances to soil to catalyze natural attenuation processes(Concas and Cao, 2004).

The Asa River is one of the two major rivers in Ilorin, Kwara State, Nigeria. It receives effluents from a beverage, soap and detergent, metal fabricating industries, and domestic wastes .amongst others (Eniola and Olayemi, 1999).

The Asa River is used for various purposes; domestic, industrial, farming, swimming and so on, both-within and outside Ilorin town. The sediments of a River constitute a sink to pollutants that get into the water; the aquatic animals feed on the sediments and some of these pollutants get ingested and absorbed.

Therefore this research was aimed at remediating Asa River Sediment by biostimulating it with three local amendments i.e. poultry droppings, abattoir effluent and rice husk with or without N.P.K. fertilizer.

MATERIALS AND METHODS

Site Description

The research was carried out at the University of Ilorin Dam, Ilorin, Kwara State, Nigeria. The site was located in the Southern Guinea Savanna (SGS) belt at longitude N08^{0}28.049’ and latitude E004^{0}39.798’, approximately 344.7m above the sea level. The average temperature is 28^{0}C and an annual rainfall is 1100-1400mm per annum.

Sample Collection

Sediments were collected from four different locations which include Amilegbe (N08^{0}29’ 42.33”, E004^{0}33’53.9”), Post office (N08^0 28’29’ 16.6”, E004^{0}33’39.6”), Unity (N08^0 28’ 28’50.3”, E004^{0}33’40.6”), Coca-Cola (N08^0 28’ 26.7”, E004^{0}33’40.6”). These samples were mixed to form a single composite sample. Soil sediments were collected from the dredged part of the river and part of the soil samples were air-dried and sieved through 2mm sieve for pre-planting soil chemical properties analysis and determination of heavy metal concentration contained in the sediment.

The organic amendments used include rice husk, abattoir effluent and poultry dropping. Rice husk was gotten from Rice Milling Market at Iyana Oja Gboro, Ilorin, while abattoir effluent was collected from Ilorin Abattoir Center, Ipata market, Ilorin and poultry dropping from Unilorin Poultry Unit at the Teaching and Research Farm, Ilorin, Kwara State. All samples were collected in clean sacs and plastic containers as appropriate prior to analysis and field incorporation.

Land Preparation

The experimental site was ploughed, harrowed and ridged after clearing. The contaminated soil was deposited at the surface of the soil at a rate of 50kg per plot (given a total of 41, 67 t/ha) to a depth of 30 cm on which planting was done. Each operation had a three days interval. The land was arranged in plots (3m x 4m) with four ridges per plot.

Experimental Layout

Randomized Complete Block design in split plot arrangement was adopted, using three (3) treatments: Rice Husk (RH), Poultry dropping (PD) and Abattoir Effluent (AE) at two levels with or without NPK, having three (3) replicate. The treatment combination followed a randomized arrangement.

Planting

One seed of Low nitrogen tolerant population white (LNTPw) maize was planted per hole at a spacing of

75 x 25cm on a 3m x 4m plot having a total of 40holes per plot which gave a plant density of 40stands per plot, where the two end rows served as the border rows.

Management Practices

Abattoir effluent of1.3 t/ha and 2.6 t/ha, rice husk and poultry dropping of 10 t/ha and 15 t/ha were incorporated into the soil at two weeks prior to planting to ensure decomposition and mineralization, while NPK fertilizer (20:10:10) was applied 3 weeks and 5 weeks after planting at a rate of 120kgN per hectare. Supplementary weeding was done at 3 weeks after planting and six weeks after planting prior to harvesting. The experiment was carried out in dry season and water was supplied through irrigation at an interval of 3days.

Chemical Properties of Sediment

Asa River Sediment were analyzed for pH in H_2O and KCl, Nitrogen, Organic carbon, Organic matter, Calcium, Magnesium, Sodium, Potassium, Acidity, Available P, Cation Exchangeable Capacity, Iron, Manganese, Zinc, Copper, Cobalt, Chromium, Cadmium, Nickel and Lead.

Soil Chemical Analysis

The pH was determined by the method outlined by Bates (1954) using an electronically Jenway 3015 pH meter at ratio of 1:2.5 insoil/water and KCl, Exchangeable acidity of the soil was determined by titration method using 1N KCl extract as described by Rhoades (1982). Organic carbon was determined using wet oxidation method of Walkley and Black (1934) as described by Jackson (1996) while available phosphorus was determined using Bray 1 (Bray and Kurtz, 1945) method and Nitrogen was determined using micro-Kjelhdal distillation method by AOAC (1999).

Exchangeable cations of calcium, magnesium, potassium and sodium were extracted with an excess of 1M NH_4OAc (ammonium acetate) as described by Anderson and Ingram, 1993. Effective cat ion exchangeable capacity (ECEC) was calculated by the summation of exchangeable bases (Ca, Mg, K, Na) and exchangeable acidity.

Heavy metals were determined by weighing 5g of air-dried soil sample in a 250ml of plastic bottle fitted with an air tight screw cap. 50ml of 1% ethylenediaminetetracetic acid (EDTA; which was gotten by dissolving 10g of EDTA in 1000mls of water), added and shaken for 1hour. The suspension was filtered using Whatman Filter Paper No. 42. The filtrate was then analyzed using atomic absorption spectrophotometer (AOAC, 1980).

Extraction of heavy metals (Cr, Cd, Pb, Ni, Cu, Zn, Co, Mn, Fe) was done by weighing 1g of dried grounded plant tissue and seed into 100ml of beaker and 5ml of nitric acid ($HN0_3$) and 2ml of perchloric acid ($HCl0_4$) and cover with watch glass. It was then digested and heated to a final volume of 3-5ml. 10-15ml of distilled water was added and the digest was filtered through an acid washed filter paper into a 50ml volumetric flask. The filtrate was then analyzed using Atomic Absorption Spectrophotometer (Linder and Harley, 1942).

Statistical Analysis

Analyses of variance was carried out using Genstat and mean values was separated using the Duncans multiple range test (DMRT) at $P \leq 0.05$ as outlined in Kerr *et al.* (2002).

RESULT AND DISCUSSION

Table 1: Initial analysis of soil and organic amendment

Chemical Properties	Soil	Abattoir Effluent	Rice Husk	Poultry dropping
Nitrogen%	0.07	1.06	0.27	0.71
Available P	0.046	24.52	26.30	11.92
Exchangeable Ca (Cmol/kg)	2.79	11.58	9.29	33.87
Exchangeable Mg (Cmol/kg)	0.14	2.61	4.97	17.85
Exchangeable K (Cmol/kg)	0.02	4.55	3.27	16.93
Exchangeable Na (Cmol/kg)	0.11	0.11	0.81	0.14
Sand	75.96			
Silt	11.28			
Clay	12.76			
Textural Class	Sand			
Organic carbon%	0.5			
Organic Matter %	0.87			
pH in H_20	9.3			
pH in KCl	8.9			
Acidity	0.4			
Cation exchange capacity	3.06			
Chromium mg/kg	25.3			
Cadmium mg/kg	0.5			
Nickel mg/kg	2.5			
Lead mg/kg	9.1			
Manganese mg/kg	350.5			
Iron mg/kg	25,250			
Copper mg/kg	9.65			
Zinc mg/kg	54.7			
Cobalt mg/kg	1.9			

The table 1 below shows the initial soil chemical properties of Asa River sediment, in which the sediments were observed to be sandy, organic matter content of the sediment was ranked low at (0.0.87%), while the nitrogen content of the sediment also ranked as low (0.07). The pH of the sediment showed 8.9 in KCl which means that the sediment was alkaline in nature and available phosphorus was also seen to be extremely low (0.046). Calcium was observed to be low, magnesium and potassium were also observed to be extremely very low and sodium also observed to have low value (0.11). Cation exchange capacity of the sediment was observed to fall below the range considered to be low. The chemical analysis of the sediment showed that the soil is low in terms of fertility. The heavy metal analysis of the sediment revealed that all metals fall below maximum permissible limit as set by USEPA except manganese (350.5mg/kg). Table 1 also revealed that abattoir effluent has a high nitrogen content of (1.06) as compared to rice 0.67 and poultry dropping of 0.71% respectively. Table 1 further revealed that rice husk has the highest total phosphorus level of 26.30 (mg/l) which is followed by poultry dropping and the least was abattoir effluent, potassium was also observed to be highest at abattoir effluent (0.55) which was then followed by poultry dropping and rice husk being the least.

Table 2: Effect of different levels of organic wastes on heavy metal availability in soil after cropping

Treat./Levels	Co (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Ni (mg/kg)
Control	0.300	54.23	0.023	0.010	1.53	0.64	2.200	0.560	0.03
RH10 t/ha	0.250	54.00	0.060	0.010	1.70	0.66	3.600	0.520	0.10
RH15 t/ha	0.200	29.43	0.023	0.001	0.97	0.37	2.000	0.450	0.07
RH10 t/ha + NPK	0.180	33.90	0.030	0.001	1.27	0.36	1.467	0.377	0.07
RH15 t/ha + NPK	0.280	53.20	0.030	0.001	1.77	0.70	3.600	0.410	0.07
Control	0.300	54.23	0.023	0.010	1.53	0.64	2.200	0.560	0.03
AE 1.3 t/ha	0.170	28.97	0.020	0.000	1.40	0.41	1.967	0.460	0.10
AE 2.6 t/ha	0.240	56.97	0.017	0.010	0.77	0.36	1.800	0.247	0.10
AE 1.3t/ha + NPK	0.250	39.10	0.030	0.010	1.50	0.70	2.533	0.580	0.00
AE 2.6 t/ha + NPK	0.340	49.50	0.033	0.010	1.57	0.54	2.400	0.480	0.03
Control	0.30	54.23	0.023	0.010	1.53	0.64	2.200	0.560	0.03
PD10 t/ha	0.34	69.13	0.017	0.001	1.47	0.63	2.233	0.383	0.10
PD15 t/ha	0.35	72.27	0.027	0.010	1.97	0.83	5.200	0.727	0.10
PD10 t/ha + NPK	0.26	49.43	0.020	0.003	1.57	0.70	3.867	0.547	0.03
PD15 t/ha + NPK	0.27	51.37	0.027	0.010	1.23	0.68	2.167	0.527	0.03
SED	0.035	2.887	0.08	0.003	0.282	0.076	0.483	0.069	0.033
LSD(0.05)	*	***	*	*	*	***	***	**	Ns
USEPA	50	80	400	3	300	200	NL	50	50

Key: NS: Not significant, NL: No limit, PD: Poultry dropping, AE: Abattoir Effluent, RH: Rice Husk, USEPA: United State Environmental Protection Agency, * Significant at 0.05%, * * Significant at 0.001%, ***Significant at <0.001%, LSD(0.05); Least significant difference across the column.

Table 2 shows that all organic amendment were effective in reducing heavy metal concentration in the sediment and were all significant at $p<0.05$ except Ni. Table 2 shows that the highest reduction in Co observed at AE 1.3t/ha and least reduction at PD15t/ha. Similarly, Mn was also observed to be significant at $p<0.001$ with the highest reduction in concentration of Mn observed at AE 1.3t/ha and the least reduction was observed at PD15t/ha. Cr had its highest reduction at AE2.6t/ha and PD10t/ha while the least reduction was observed at RH10t/ha. Table 2 further revealed for Cd the highest reduction in concentration observed at AE 1.3t/ha and the least reduction observed at control, RH10t/ha, AE 2.6t/ha, AE 1.3t/ha+NPK, 2.6t/ha+NPK, PD15t/ha and PD15t/ha+NPK. Pb highest reduction was observed at AE 2.6t/ha and the least reduction was at PD15t/ha. Similarly, Zn was also observed to have its highest reduction in concentration RH10t/ha+NPK and AE 2.6t/ha and the least reduction at PD 15t/ha. However, Fe was observed to have its highest reduction at RH10t/ha+NPK and the least reduction at PD 15t/ha. Table 2 further shows that Cu has its highest reduction in concentration at AE 2.6t/ha and the least reduction in concentration at PD15t/ha. Table 2 shows that heavy metals in soil after cropping follows these trend: Mn > Fe> Pb> Zn> Cu> Co> Ni> Cr> Cd.

Table 3: Effect of different levels of organic wastes on heavy metal availability in tissue after cropping

Treat./Levels	Co (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Ni (mg/kg)
Control	0.07	12.1	0.02	0.003	0.10	0.38	1.20	0.19	0.00
RH10 t/ha	0.06	4.70	0.01	0.003	0.13	0.67	2.00	0.13	0.00
RH15 t/ha	0.11	6.20	0.01	0.003	0.27	1.16	2.70	0.19	0.00
RH10 t/ha + NPK	0.12	4.90	0.02	0.000	0.10	0.80	1.97	0.16	0.00
RH15 t/ha + NPK	0.06	5.90	0.03	0.007	0.17	1.16	1.90	0.15	0.03
Control	0.07	12.1	0.02	0.003	0.10	0.38	1.20	0.19	0.00
AE 1.3 t/ha	0.09	5.80	0.01	0.000	0.12	0.61	1.47	0.18	0.00
AE 2.6 t/ha	0.09	8.00	0.03	0.007	0.20	1.11	0.77	0.14	0.00
AE 1.3t/ha + NPK	0.09	10.60	0.04	0.000	0.27	0.58	2.83	0.23	0.00
AE 2.6 t/ha + NPK	0.06	2.00	0.01	0.003	0.17	1.33	0.30	0.15	0.00
Control	0.07	12.10	0.02	0.003	0.10	0.38	1.20	0.19	0.00
PD10 t/ha	0.10	12.50	0.03	0.000	0.20	1.02	1.73	0.26	0.03
PD15 t/ha	0.09	7.50	0.03	0.003	0.23	0.28	2.07	0.17	0.03
PD10 t/ha + NPK	0.07	7.00	0.02	0.003	0.20	0.85	2.50	0.18	0.00
PD15 t/ha + NPK	0.08	1.50	0.02	0.007	0.20	0.64	1.11	0.31	0.00
SED	0.022	5.010	0.009	0.004	0.043	0.197	0.917	0.052	0.022
LSD(0.05)	ns	ns	ns	ns	ns	***	ns	ns	ns
USEPA	50	30	50	0.5	0.3	50	1000	20	2

Key:
NS: Not significant, NL: No limit, PD: Poultry dropping, AE: Abattoir Effluent, RH: Rice Husk, USEPA: United State Environmental Protection Agency, * Significant at 0.05%, * * Significant at 0.001%, ***Significant at <0.001%, LSD(0.05); Least significant difference across the column.

Table 3 shows that Co, Mn, Cr, Cd, Pb, Fe, Cu and Ni were not significant at $p<0.05$ except Zn. The table revealed that Zn was significant differences in terms of uptake by plant tissue due to differences in treatments applied with the highest reduction in plant tissue observed at PD 15/t/ha and the least reduction in uptake observed at AE 2.6t/ha+NPK

Table 4: Effect of different levels of organic wastes on heavy metal availability in grain after cropping

Treat./Levels	Co (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Ni (mg/kg)
Control	0.03	0.29	0.06	0.007	0.03	1.34	0.10	0.05	0.00
RH10 t/ha	0.15	0.11	0.03	0.010	0.00	1.12	0.10	0.05	0.00
RH15 t/ha	0.03	0.43	0.12	0.000	0.17	1.34	0.17	0.04	0.00
RH10 t/ha + NPK	0.02	0.16	0.09	0.000	0.00	1.48	0.17	0.06	0.00
RH15 t/ha + NPK	0.03	0.22	0.05	0.000	0.10	1.37	0.13	0.06	0.00
Control	0.03	0.29	0.06	0.007	0.03	1.34	0.10	0.05	0.00
AE 1.3 t/ha	0.00	0.22	0.07	0.000	0.17	1.32	0.17	0.05	0.00
AE 2.6 t/ha	0.02	0.17	0.02	0.010	0.20	1.09	0.10	0.05	0.00
AE 1.3t/ha + NPK	0.00	0.13	0.03	0.000	0.07	0.68	0.13	0.05	0.00
AE 2.6 t/ha + NPK	0.00	0.003	0.03	0.007	0.07	1.00	0.20	0.09	0.00
Control	0.03	0.29	0.06	0.007	0.03	1.34	0.10	0.05	0.00
PD10 t/ha	0.03	0.20	0.06	0.003	0.03	1.08	0.10	0.04	0.00
PD15 t/ha	0.00	0.10	0.02	0.007	0.07	0.36	0.30	0.03	0.03
PD10 t/ha + NPK	0.00	0.10	0.05	0.010	0.03	1.25	0.17	0.03	0.00
PD15 t/ha + NPK	0.00	1.62	0.05	0.010	0.07	1.33	0.23	0.06	0.00
SED	0.033	0.344	0.038	0.002	0.055	0.256	0.078	0.017	0.012
LSD(0.05)	ns	*	ns	*	ns	*	ns	ns	ns
USEPA	50	500	2.3	0.2	0.3	99.4	425.5	50	67

Key:
NS: Not significant, NL: No limit, PD: Poultry dropping, AE: Abattoir Effluent, RH: Rice Husk, USEPA: United State Environmental Protection Agency, *Significant at 0.05%, ** Significant at 0.001%, ***Significant at <0.001%, LSD(0.05); Least significant difference across the column.

Table 4 shows that only Mn, Cd and Pb were observed to be significant at $p<0.05$ interms of heavy metal uptake in grain after harvest. Mn was observed to have had its highest reduction in concentration at AE 2.6t/ha+NPK and the least reduction at PD 15t/ha+NPK. It was also observed in table 4 that Cd has its reduction in concentration at RH15t/ha, RH10t/ha+NPK, RH15t/ha+NPK, AE 1.3t/ha and AE 1.3t/ha+NPK, while the least was observed at PD 10t/ha+NPK and PD 15t/ha+NPK. Zn was observed to have its highest reduction in concentration at PD15t/ha and least reduction was observed at RH 10t/ha+NPK.

The finding of that is organic wastes are an effective technique in remediating contaminated soil and this agrees with the findings of Sauvè *et al*., 2003 who asserted that organic matter acted as a primary sorbent of heavy metals in contaminated soils. Basta and McGowen (2004) also opined that addition of organic matter amendments immobilize heavy metals for soil amelioration and as a result, increase pollutant removal efficiency (Wang *et al.* 2012, Clemente *et al.,* 2003). Several researchers have also explored the potential of compost in remediating heavy metals (Roman et al., 2003; Castaldi et al., 2005; Simon, 2005).

Furthermore, elevated or increased heavy metals in plants from the amended soil could be attributed to the high nutrient content of the poultry feed confirm earlier assertion by other investigators Mbah and Asegbeke, (2006).

CONCLUSION

From the result of this study, it can be concluded that; Abattoir effluent was found to be more effective in bioremediating heavy metal in Asa River Sediment at sole application of 1.3 t/ha and 2.6 t/ha than poultry dropping and rice husk, and its combination with NPK at 2.6t/ha was also observed to have had the highest reduction interms of uptake by plant tissue.

Abattoir effluent outperformed poultry dropping and rice husk and possible reason for this might be because abattoir effluent contains higher nutrients from different sources (blood, urine, feces, hides, water, bones etc), and also because it is in liquid form which makes mineralization faster as compared to poultry dropping and rice husk which takes longer time to mineralize. Furthermore, the liquid nature of abattoir effluent provides a larger surface area which increases the rate at which these metals form organic complexes with abattoir effluent.

Therefore, the findings of this research have established the fact organic wastes are an effective technique in remediating contaminated soil.

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